XVII.

THE SEWERAGE OF MEMPHIS, TENN., AFTER A TRIAL OF ONE YEAR.

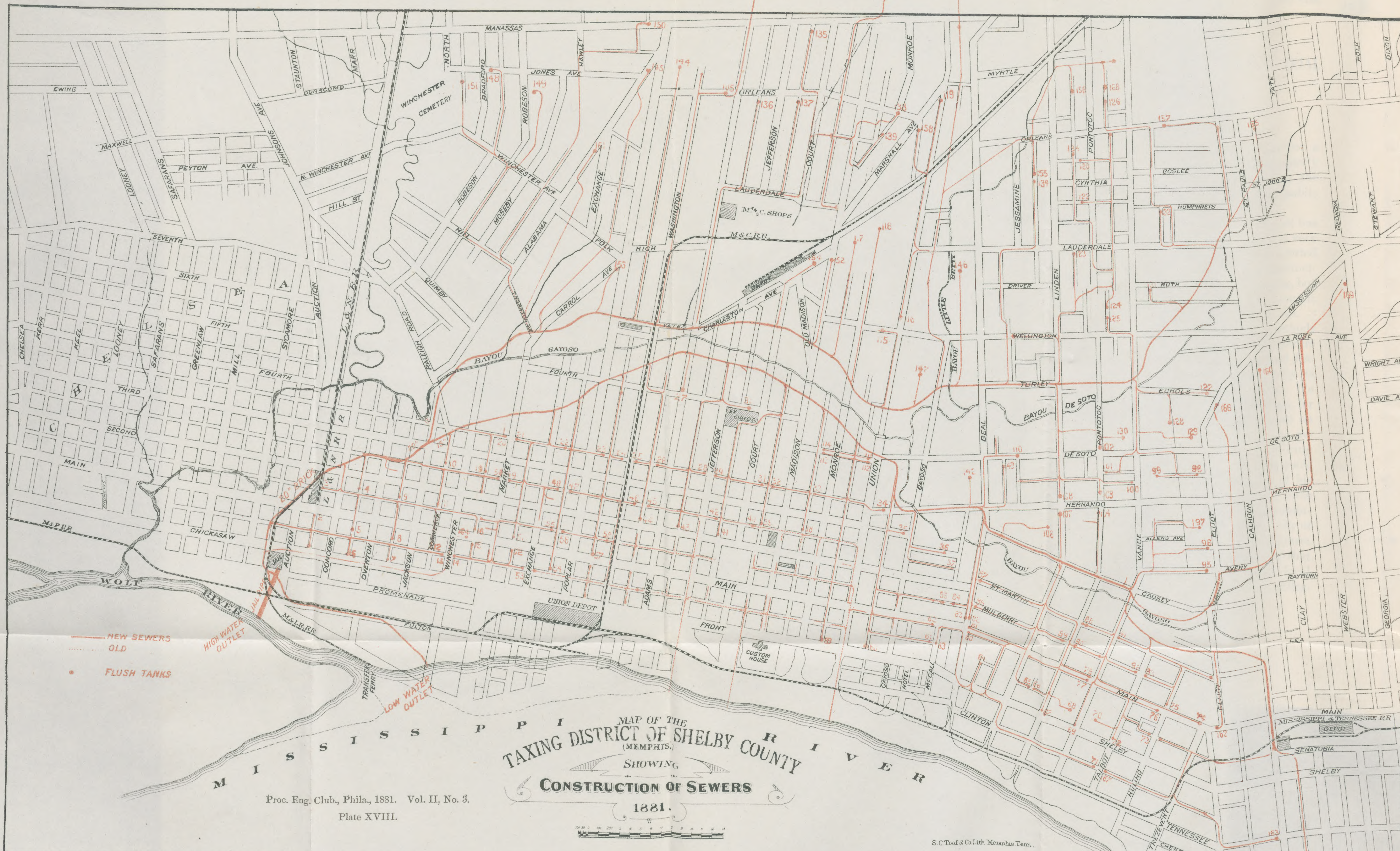
By WM. HENRY BALDWIN, Member of Club.

Read April 16th, 1881.

The sewerage system of Memphis has now been in operation a little more than one year. The principal lines from the easterly and westerly portions of the city were brought together in the latter part of July, 1880, and the sewers were then ready for public use, although many houses had already been connected.

As this is the first instance where the system here adopted has been applied upon anything like so extensive a scale, it has very naturally attracted considerable attention and persons interested in such matters have been desirous to know what are its distinctive features and wherein it differs from the ordinary practice, but more especially to find out its practical operation when brought down to everyday use—in fact to know how it actually works.

Much has already been written on the details and methods employed in constructing the sewers of Memphis. Engineers and others have commented upon and criticised the general features of the system, and have discussed the claims made by its author to originality in its application to towns and cities. We will not attempt to say anything about originality of design, for its author is well known to be fully able to speak for himself on this subject. Nor do we propose to advocate or defend the peculiar system of sewerage adopted in Memphis, but only to bring together such information as is available from observations made thus far, which may help the reader to form an opinion of his own. We will proceed then, in the first place, to consider some local topographical and other features having a controlling influence in the application of any system of sewerage to the city of Memphis,—secondly, to review some of the distinctive features and characteristics of the system of sewerage adopted for that city, but having a general application independent of any local conditions and which constitute a marked and important differ-



Proc. Eng. Club., Phila., 1881. Vol. II, No. 3.
Plate XVIII.

ence between this and any other method of sewerage heretofore used in the public works of cities, and, finally, to note some observations made during the past year, showing the disposal of domestic and household waste by water-carriage; the amount and nature of the deposit in the pipes and the method successfully adopted for its removal; the quantity of water discharged through the sewers at different hours throughout the day and night; the velocity of flow of water through the pipes and the consequent length of time required for matters introduced into the sewers to find their way out and be discharged into the river; and any other items of interest having a tendency to show the practical operation of the sewers during the first year of their service, and their condition at the present time.

The writer is indebted to the courtesy of Major J. H. Humphreys, Engineer in Charge of the works, for notes and information very cheerfully furnished for this paper.

When the writer arrived in Memphis, only a few weeks after the abatement of the fever which raged so fearfully during the summer of 1879, it was thought essential to secure a residence, light, airy and with plenty of sunshine, and, at the same time, it seemed desirable to find a place overlooking the river where one could enjoy the beautiful scenery which northern people expect on the banks of a great river. But Memphis, although built on a bluff, does not overlook the river. One or two principal streets, at an elevation of forty or fifty feet above the water, are occupied by warehouses, and are used for commercial and other business purposes, while the rest of the city slopes rapidly away towards the interior.

Drainage is therefore *from* the Mississippi River and not towards it. About half a mile back from the bluff a small stream winds along through an alluvial bottom, into which it has cut its way to the underlying stratum of sand and gravel, leaving perpendicular banks from twelve to fifteen feet high on each side. The principal streets are bridged across this stream and rise again quite rapidly to the suburban and rural portion of the city beyond. The flow of this stream, called the Bayou Gayoso, is in a northerly direction, its banks become gradually lower and the alluvial bed through which it flows spreads out to a greater

width, until finally it discharges into the Wolf River, about half a mile above the junction of that stream with the Mississippi. Although the above description is somewhat voluminous the stream itself is quite insignificant at most times, but, as it lies wholly within the city, having the business and thickly populated part on one side, with the suburban and rural on the other, it will be seen that, though small, it plays an important part in the sanitary condition of the city.

The Mississippi River, once or twice every year, and sometimes oftener, rises to a height of from fifteen to twenty feet above its ordinary level and, at such times, its waters back up into the small stream just described, overflowing its banks for a length of more than a mile within the city, submerging the low grounds in its vicinity and keeping them under water for weeks at a time. This stream serves a very good purpose in carrying off the rain water from the streets and gutters, but it is evident that, if all the waste and sewage of the city were allowed to flow into it, the districts submerged would, on the subsidence of the water, be covered with slime and filth and, when exposed to the hot sun of that climate, would seriously impair the sanitary condition of the city.

In designing any system of sewerage there was then no alternative but to provide collective sewers, one on each side of the bayou, to receive the flow as it comes down the streets and alleys and to convey it away to a point whence it will not return. It was necessary to have these collective sewers as near as possible to the bayou, both to avoid deep cuttings and to have as narrow a space as possible between the two lines.

There are no streets or alleys running in a direction at all suitable for the purpose, as Memphis is laid out on the rectangular plan, hence it was necessary to lay the collective sewers through private property for almost their entire length, in fact considerably more than two miles. An undertaking of that kind required great boldness on the part of those who designed it, and could not have been accomplished without extraordinary powers granted by the State. But the citizens of Memphis were fully in sympathy with the enterprise and willing to do almost anything to escape the terrors of an epidemic, so that almost invariably the right of way was conceded without opposition or cost.

A point of discharge having been selected, it was ascertained that a uniform fall of one in six hundred could be secured for the main sewers. An important condition of the system may be mentioned in the outset, namely that no angles or sharp turns should be made in any of the sewers, especially in the mains. In view of the fact that a sewer through private property could not be easily retraced when once buried out of sight unless carefully located, and also to have the lines as nearly straight as possible, the mains were laid out in curves and tangents with the same care as a railroad, points being fixed at intervals of twelve and one half feet to secure accuracy of alignment, and the radius of curvature was made as great as possible, seldom less than one hundred feet on the westerly side of the bayou, while on the easterly side, where obstructions were not so serious, a uniform radius of three hundred feet was selected and secured with but few exceptions.

As the duty of locating these lines through private property devolved upon the writer, he may be unduly impressed with some of the details of this part of the work, and still retains clearly in mind the strife to get a line through cotton sheds and back yards, among shanties and high brick walls, and beneath dwellings, without cutting away the brick columns on which most of the houses are built in that climate, and at the same time to maintain a direct line with true curves. The most serious obstacle met with was the large underground cisterns used to secure the domestic supply of rain water. The people of the South thoroughly understand and appreciate the art of preserving rain water for drinking purposes, and when a cistern proves to be a good one, the owner is unwilling to give it up, as the water of a new cistern is sure to be bad for a year or more, and, from some unaccountable reason or others, is very likely to be worthless altogether. The value of good rain water cisterns is still further enhanced when compared with the muddy water pumped directly from the river for the city supply. One may then very well imagine the disappointment and disgust felt by a party of engineers upon discovering one of these great cisterns directly in the way of a line carefully spied out after days of labor. But, like all things in engineering, the exercise of pa-

tience and perseverance carried the work along to its completion.

Without trespassing further upon your patience with details of a preliminary nature, we may say that the main lines have been constructed on each side of the bayou according to the design sketched above. For local reasons they were brought together and united in a brick sewer, about half a mile from the outlet. One of the lines is carried over the bayou to effect this junction, and is supported on a wrought iron bridge made for the purpose, resting on brick piers and having a clear span of 61 feet 8 inches. The sewer itself over the bridge and its approaches is of cast iron with lead gaskets. The approaches to the bridge on each side consist simply of the pipe, supported by brick piers, one under each joint. As soon as the approaches come near enough to the ground and far enough from the stream to be covered with a mound of earth, the sewer is built of ordinary vitrified clay pipe, supported on small arches resting on brick columns, the pipe being protected from accident and the action of the weather by a row-lock of brick turned over it, four (4) inches thick. This method of construction upon brick arches was frequently resorted to in crossing ravines or in low ground too unstable to sustain the sewers without artificial support. They were of uniform design, having arches of eight (8) feet span and one (1) foot rise, resting on columns of brick, extending down to a good foundation.

From the above description it will be seen that the Memphis system of sewerage consists,

First, of main lines laid with a uniform fall (two inches in one hundred feet) and in practically straight lines.

Second, of branches discharging into the mains at each of the streets or alleys crossed until the mains themselves are gradually reduced in size, as the supply of water diminishes, and they in turn become branches. The sewerage of Memphis is then divided into many small areas, each of which may be properly regarded as a small drainage system of its own independent of all the others.

The sewers of Memphis are designed to remove as quickly and completely as possible all the liquid wastes of the house-

hold and the discharge from water-closets. The amount of water furnished by a city supply affords a basis for estimating the amount to be carried off by its sewers, provided all the city is furnished with sewers, and also that no storm water be admitted. To be sure, much water is supplied from wells and cisterns, especially in a southern city, but this is doubtless more than offset by water used in garden-hose, street-sprinkling and in other ways, where it does not find its way to the sewers. Knowing then approximately the amount of water supplied, the sewer pipes may be so proportioned as to be nearly filled each day and thus kept thoroughly washed out. But it is essential that no storm water be admitted, not even that which falls upon the roofs; for the amount of rain falling on the roof of a dwelling in course of a few hours is so entirely disproportionate to the amount of water actually used by the occupants of the house during the same time, that a system of drains designed to convey only the domestic water supply would be entirely inadequate to carry off the rain water even from the roof, while on the other hand a system of pipes large enough to carry off the rush of water from an occasional storm would be many times too large to conduct the domestic supply during all the fair weather in the year. It may seem superfluous to emphasize this feature of the Memphis system of sewerage further than to say that the entire and not the partial exclusion of storm water is one of the essential and vital conditions upon which its success depends, for the reason, among many others, that this is the only possible way in which a uniform daily flow of water can be secured sufficient to flush out the pipes and keep them clean.

Pipe sewers from ten to eighteen inches in diameter have been used for many years in some of our principal cities. More than fifty miles are now in successful operation in New York. These pipe sewers carry a fair weather flow seldom exceeding five or eight per cent. of their capacity, a pipe eighteen inches in diameter usually having not more than half an inch to perhaps two inches of water in it. Dependance has to be placed on the occasional action of storms to wash out any deposit left by this small daily flow, but when storms are long delayed, these deposits lie in the pipes and fester and decay for days and weeks, often be-

coming caked so hard and solid as to resist the action of the storm when it does come.

If there could be a storm every day or, in other words, if the pipes could be filled full of water every day, the agent on which we now depend for occasional relief would then be in constant operation. This is precisely the condition of the Memphis sewers; the flow at night is small, but in the middle of the day it amounts to a storm in pipes properly proportioned.

It seems reasonable to expect that, whenever a pipe can be supplied with water enough daily to fill it half full, it will be kept clear without artificial means. Certainly it seems more likely than if filled only at the infrequent and irregular occurrence of storms which may be delayed for weeks or months.

In estimating the size of the pipes to be used for the Memphis sewers it was designed that the pipe should be filled half full by the ordinary midday flow, leaving the other half for contingencies and for future increased demands. This ratio was maintained by reducing the size of the pipes, toward the head of the system, in proportion to the diminished quantity of water to be carried off. But there is a practical limit beyond which the size of the pipes cannot be reduced. Assuming the house drains to be four inches in diameter and providing for an enlargement at their junction with the public sewer, we are limited to a diameter of six inches as the smallest practical size for the public sewer. The usual rates of fall in Memphis are from six to twelve inches per hundred feet, sometimes more. The amount of water which a six inch pipe will carry away at these rates of fall is known to be from four to six thousand gallons per hour, and the velocity of flow from one hundred to one hundred and fifty feet per minute. It would require a great many dwellings to furnish so large a supply of water as that. By reference to the gaugings of the flow of water in the Memphis sewers, given on another page, it will be seen that the greatest discharge of water in any one hour is only about twenty per cent. more than the average throughout the twenty-four hours of the day. At this rate, to secure a supply of 5000 gallons in one hour would require an average of 4167 gallons per hour, or a total of one hundred thousand gallons per day, as much water

as would be likely to be furnished by two hundred ordinary house drains.

It is a new departure in engineering to assert that a six inch pipe laid on an inclination of one in one hundred and fifty is large enough to drain two hundred dwellings, but the above line of reasoning appears to indicate as much, and the experience of the past year in Memphis proves the efficiency of small pipes far more conclusively than any mere pen and ink logic could do.

But, unless the supply of water is great enough to fill the pipes at least half full every day, it is well known that they will become gradually filled with sediment, and will require some artificial means of keeping them clear. The most effective artificial means known which can be automatically applied is to discharge at intervals a quantity of water large enough to rush through the pipe and clear its way. Five thousand gallons per hour is only eighty-three gallons per minute, and it is not necessary to maintain the flow for a very great length of time.

The Field flush-tank used in Memphis discharges 112 gallons of water in a little less than a minute directly into the head of each of the six inch pipes, and the rush of this water has been distinctly observed for a distance of 1400 feet or more, according to the rate of descent of the sewer.

It remains for experience to prove if this quantity of water is large enough to effectually wash out the pipes when discharged once or twice a day. The quantity of water required to supply the flush-tanks of the city is almost inappreciable for, while the sewers discharge about two million gallons daily, the amount of water furnished by the flush-tanks would be but 30,000 gallons if all were emptied twice a day.

It remains also for experience to show if the tanks will work when let alone or when subjected to only a reasonable amount of attention. In this particular we have the experience of a little more than one year, and the officers in charge of the sewerage department of Memphis assert that their operation has been successful.

Very few tanks have caused any trouble, and these usually from defects in the castings or in setting them. Such defects were soon discovered and remedied. It would be very bold to

assert that the flush-tanks used in Memphis are not susceptible of improvement. Some improvements have already been made and doubtless others will be from time to time, but the principle on which they operate appears to be established and their success demonstrated. Nor is it likely that the size of the tanks has been correctly determined in every instance, but as a flush-tank costs no more than an ordinary inlet-basin or man-hole, and as only one is required for each line of sewer, their re-construction would be but a trifling matter if a different size should be found necessary.

Before leaving the subject of flush-tanks it may be well to allude to the mistaken impression in the minds of some that the whole system of sewers require to be flushed, or that there is any concert of action of the tanks with each other, or that their discharge need be regulated in any way to conform to each other.

A moment's reflection will show that, as they are situated only at the dead ends of the sewers they are necessarily widely apart; each one operates only upon the sewer immediately below it and hence is entirely independent of all the others.

There is nothing above it to be obstructed if it gets out of order, hence it can be taken up and repaired or replaced if need be without any interference with the rest of the system, and finally no part of the sewers needs flushing except the dead ends of the small pipes.

So much has already been written about the details of the construction of the Memphis sewers, the manner of laying the pipes and making house connections, and many other matters interesting, but now grown familiar, that allusion will only be made incidentally to these things; but there are two considerations of importance which will be briefly noted. FIRST, the ventilation of the sewers, and SECOND, the flow of water in them. Both these subjects have now been tested sufficiently to furnish information of interest and value. The first of these subjects involves the question of sewer gas. The other may enable us to ascertain how long a time sewage remains in the pipes before it is discharged into the river. The two considerations when taken together will enable us to estimate the possibility of the decomposition and decay of sewage while it remains beneath the streets of the city.

We have already considered the general plan of the sewerage system, and have seen that it consists first of a brick sewer twenty (20) inches in diameter and about 4,000 ft. long, receiving the discharge of two pipe lines, one of fifteen (15) inches diameter, and the other twelve (12) inches.

Memphis is laid out on the rectangular system of streets and alleys. Sewers are laid in the alleys, and usually descend in direct lines and discharge into the mains within a distance of half a mile or less of their source. The whole system then may be said to consist of numerous branches, each of which is independent of all the others, is usually not more than half or three-quarters of a mile in length and may properly be regarded as a small system of its own.

A description of the ventilation of one of these branches will apply equally well to any other, and hence to the whole sewerage system.

The ventilation is perfectly simple and equally effective. FIRST, a fresh air inlet is placed in each branch near its junction with the main sewer. SECOND, every house drain is required by law to be, and in fact is, left open without any main trap, and is extended up through the several floors of the house, by means of an iron soil pipe four inches in diameter, passing through the roof and opening into the open air above. By this means a free circulation of air is secured at all times and no back pressure or accumulation of foul gases or vapors is possible. There is not much movement of air through the sewers, but where any draught has been observed it has been from the street inward to the sewer, as proved by the fact that a burning piece of paper is drawn into and not blown out of the fresh air inlets. Every house drain is a ventilator almost as large as the sewer itself, and, as they all extend above the roofs of the houses, some terminate at a much greater elevation above the ground than others, hence the circulation of air is doubtless upward in some and downward in others. It is perhaps a matter of regret that more extended observations have not been made on this subject, but, on the other hand, the fact that nobody has been led to investigate the subject goes far to prove that the operation of the ventilation system is entirely satisfactory. In fact, the great number of ventilators

afforded and their size, as compared to that of the sewer, render the accumulation and stagnation of foul air impossible.

As to the flow of water some observations have been made by passing floats through the sewers and noting the time required for them to go from one man-hole to another. By this means the velocity in the mains has been ascertained to be about two and one-half feet per second. These have a grade of only two inches per hundred feet, but the branches are much steeper, having a fall usually about six inches in one hundred feet, hence we may conclude that the flow of water in them is more rapid than in the mains. From all available information we may safely estimate the average velocity throughout the city to be not less than two feet per second. On this subject the engineer in charge of the work, Major J. H. Humphreys, in a recent letter says, that he should consider an estimate of two feet per second throughout the entire city a very safe estimate as, in his opinion, the flow in most places would be considerably greater. The main sewers are only about two miles in length. Assuming a velocity of two feet per second or one mile in three-quarters of an hour, water would traverse their entire length in an hour and a half. The branches are usually about one-half to three-quarters of a mile in length, and at the same velocity water would run through the longest in half an hour. Few, if any houses, connected with the Memphis sewers are more than two and a half miles distant from the outlet, while the vast majority are within considerably less than two miles, hence we may safely conclude that anything finding its way into any of the sewers would be discharged into the river within two hours or three at the most. This evidently allows but little time for sewage to become foul or offensive, especially as it is kept in constant motion and is exposed to fresh air all along the line, by the complete system of ventilation described above. This rapid flow not only renders the stagnation and putrefaction of water impossible during the short time it is allowed to remain in the sewers, but also prevents the collection of deposits of solid matter to any considerable extent, especially the gradual silting in of fine matter, but occasionally foreign matter will find its way into a sewer, such as rags, bunches of cotton, pieces of brick or stone, etc., not readily

carried along by the current and likely if neglected to form an obstruction. For the detection and removal of such things resort has been made to the now familiar device of passing hollow metallic balls through the pipes of a size only a little smaller than the pipes themselves. A single instance of the practical advantage of the device appears in the experiment on the twenty (20) inch brick sewer, where a ball fifteen (15) inches in diameter went through without difficulty, but one having a diameter of seventeen (17) inches was stopped by a mass of cement carelessly left in the sewer when it was built, and was thus detected. The engineer in charge of the works, Major J. H. Humphreys, in a recent letter says, that nothing more substantial has been found than rags and a sort of gelatinous deposit, which seems a fine silt bonded by what seems pulp, formed by the dissolution of paper. This is easily purged out by the use of the balls described above.

No pipes have ever been stopped by the gradual silting in of solid matter. There have been a few instances of stoppage in six-inch pipes; these have almost invariably been caused by a bone or a splinter of wood, a little longer than the diameter of the pipe, getting crosswise and forming an obstruction. The entire number of such instances to July last was twenty-one (21), and the average cost of their removal was $15 each, or a total of $300 a year in thirty-two (32) miles of sewers.

During the past winter the weather in Memphis was exceptionally cold, and much water was allowed to run to waste to prevent freezing in the service pipes. This caused some inconvenience by turning so large a quantity of water into the main sewers. The twenty (20) inch brick sewer was equal to the emergency and has never been filled full, but some of the twelve (12) and fifteen (15) inch pipes were surcharged for several weeks. This led to a series of observations and experiments. The pipes were opened in various places throughout the city by uncovering the T branches left for that purpose, and were found to have a rapid, strong flow of water and apparently clear from deposits. The six-inch branch sewers were found in every instance fully equal to the extraordinary demand, as none of them were filled more than half to three-fourths full.

Observations made on the 20-inch brick sewer consisted in passing floats from one man-hole to another, to ascertain the velocity of flow, and also by taking gaugings of the depth of water at each hour during the day and night. Similar observations have also been taken at intervals since then. The rate of fall in this sewer where the notes were taken is one in four hundred and sixty.

The first experiment made to ascertain the velocity of flow was on Friday, Dec. 17th, 1880, at 3.30 P.M. Circular floats, four (4) inches in diameter and one (1) inch thick were observed to pass from Jackson St. to Centre Alley, a distance of 1733 feet, in eleven (11) minutes and twelve (12) seconds, indicating a surface velocity of 2.58 feet per second. Depth of water 13.75 inches.

On Dec. 20th, 1880, eleven similar floats through the same sewer between the same points, with the same depth of water, indicated an average velocity of floats of 2.53 feet per second. Subsequent experiments show a velocity somewhat greater, though the depth of water was considerably less, for instance four similar floats passed from the same point through a distance of 420 feet, at an average velocity of 2.65 feet per second, although the depth of water was only 12 inches. The floats at this time could not be followed through the lower portion of the sewer, as it was submerged by the back water from the Mississippi river for several weeks in succession. See Table II, page 284.

Observations to determine the rate of discharge of water during the day and night have been made by taking gaugings of the depth of water flowing through the 20 inch brick main at Jackson street, each hour of the twenty-four, the first beginning on Monday, December 20th, at 6 P.M. A tabular statement is given on page 286, Table IV, showing the gaugings taken at this time, and also another series taken on Saturday, April 30th, 1881. In order to facilitate the examination of data thus furnished, a calculation has been made of the probable velocity and discharge in a sewer, such as the one in question, with water flowing at various depths of from one to twenty inches (full). These calculations are made according to Kutter's formula, by the use of the diagrams prepared by Rudolph Hering, for the American Society of Civil Engineers, October 16th, 1878,

Table III. The probable velocities and discharges thus computed are also placed for convenience in Table IV.

No discussion of the data and information here furnished will be made now, further than to remark that the flow of water on December 20th, was probably disturbed somewhat by slight obstructions then existing in the sewer but subsequently discovered and removed.

The large flow of water during the night when compared to the average and maximum flow may possibly suggest the suspicion that the sewers are carrying a constant flow of subsoil drainage finding an entrance through imperfect joints in the pipes. There are a good many reasons for concluding that the sewers do not carry subsoil drainage. The entire quantity of water discharged is too small for that, being less than one half the quantity pumped by the Water Company; and again the large minimum flow was maintained during the dry season when no subsoil water flowed out through the drainage tiles laid in the same trenches beside the sewer pipes.

It is a matter of regret that the hourly pumpage by the Memphis Water Company cannot be furnished together with the gaugings of the sewer during the same time. The works being on the Holly system of direct supply, this could easily be done by a concert of action among the authorities. The Water Company during the cold season last winter supplied about four million gallons daily. They now claim to be pumping nearly five millions, but the flow through the sewers is apparently less than it was at that time.

The tabular statement of water supplied by the Holly system at Burlington, Iowa, for which we are indebted to the courtesy of Mr. Ira Holly, superintendent, and also the record of hourly supply of water in St. Louis, derived from official reports of that city are given on page 284, but perhaps the record of high service in the city of Boston gives the nearest approach to the Memphis water supply of anything available. Table I.

The writer is painfully aware of the fact that information thus far available is much too small to afford a basis for reliable conclusions. It is to be hoped that more extended observations will be made in the future, especially on the relation between the water supply and the sewer discharge.

The subject will be continued as soon as further information can be secured.

TABLE I.

Table showing the number of gallons of water supplied during each hour of the day and night in various cities.

Hour.	Burlington, Iowa. 1881.		St. Louis. 1880.			Boston, Mass. (Cochituate High Service.) 1879.	
	Apr. 25–26.	Apr. 26–27.	Jan. 17.	Jan. 17 & 18	Jan. 18.	Jan. 21 & 22	Apr. 17 & 18
6 P.M.						111,840	87,730
7 "	32,508	40,338		620,000	700,000	115,710	90,210
8 "	27,288	31,212		610,000	660,000	113,370	87,730
9 "	26,640	30,708		610,000	700,000	114,890	75,640
10 "	24,660	28,080		555,000	700,000	117,210	75,175
11 "	24,300	26,820		570,000	560,000	94,250	69,440
12 Midnight.	23,760	24,588	570,000	560,000		104,750	63,395
1 A.M.	23,868	24,012	610,000	560,000		100,580	59,365
2 "	25,344	24,948	730,000	795,000		114,290	58,280
3 "	25,092	22,824	700,000	795,000		103,720	57,660
4 "	25,056	23,472	790,000	820,000		90,640	57,660
5 "	25,092	23,400	825,000	765,000		100,370	58,125
6 "	26,820	24,840	850,000	970,000		119,810	66,650
7 "	28,224	27,648	790,000	1,025,000		142,250	87,265
8 "	37,836	27,656	880,000	1,025,000		141,420	100,905
9 "	47,844	41,418	835,000	1,170,000		124,330	105,550
10 "	47,898	55,836	950,000	1,115,000		146,840	107,260
11 "	49,680	44,010	1,000,000	1,115,000		137,230	102,920
12 Noon.	56,700	49,032	1,000,000	1,170,000		121,420	97,495
1 P.M.	34,290	32,886	1,600,000	1,230,000		124,400	96,565
2 "	50,328	42,822	875,000	1,210,000		116,730	95,325
3 "	51,462	44,874	815,000	1,210,000		113.530	95,480
4 "	54,810	46,926	690,000	830,000		114,920	95,325
5 "	56,430	46,764	635,000	775,000		107,090	89,280
6 "	56,322	41,850	615,000	735,000			
Totals.	882,252	836,964				2,791,590	1,980,435
Average per hour.	36,760	34,874				116,316	82,518

TABLE II.

Table showing observations to determine velocity of flow of water in brick sewer at Memphis, Tenn., by passing circular floats 4 inches diameter and 1 inch thick.

Diameter of sewer, 20 inches.

Rate of fall, 1 in 460.

DATE.	LOCATION.	DISTANCE.	DEPTH OF WATER.	VELOCITY OF FLOATS.	REMARKS.
Dec. 17, 1880.	Jackson St. to Centre Alley.	1733 ft.	13.75 in.	2.58 ft. per second.	
Dec. 20, 1880.	" " "	1733 "	13.75 "	2.53 " "	Mean of 11 floats.
May 3, 1881.	Jackson to Overton St.	420 "	11.50 "	2.65 " "	Mean of 4 floats.
June 18, "	" " "	420 "	12.00 "	2.60 " "	
" "	Jackson St. to Centre Alley.	1733 "	11.50 "	2.82 " "	
July 15, "	Jackson to Overton St.	420 "	12.00 "	2.57 " "	
" "	Main to Front St.	500 "	12.00 "	2.82 " "	

TABLE III.

Table showing the probable velocity and discharge of water in a brick sewer of circular cross-section. Diameter, twenty (20) inches. Rate of fall, one in four hundred and sixty (1 in 460). Depth of water in the sewer, from one inch to twenty (20) inches.

Determined from Kutter's formula by the use of Hering's diagrams, assuming a coefficient of friction of .015.

Depth of Water in Sewer.	Portion of Perimeter of the Sewer covered with Water.	Sectional Area of Water flowing in Sewer.	Velocity of Flow per Second.	Discharge per Hour.	REMARKS.
INCHES.	INCHES.	SQUARE INCHES.	FEET PER SECOND.	GALLONS PER HOUR.	
20.0	62.83	314.16	2.45	143,932	Sewer running full.
19.0	53.81	308.28	2.70	155,650	
18.0	49.96	297.81	2.77	154,262	
17.0	46.92	284.61	2.79	148,489	
16.0	44.28	269.43	2.81	141,016	
15.0	41.89	252.74	2.80	132,192	
14.5	40.75	243.95	2.78	126,819	
14.0	39.65	234.89	2.76	121,231	Velocity of float, 2.53.
13.5	38.57	225.63	2.73	115,186	
13.0	37.52	216.16	2.70	109,139	
12.5	36.47	206.56	2.67	103,133	
12.0	35.45	196.81	2.63	96,793	Velocity of floats, 2.57—2.60—2.82.
11.5	34.43	186.97	2.59	90,555	Velocity of floats, 2.65—2.82.
11.0	33.42	177.04	2.55	84,421	
10.5	32.42	167.03	2.51	78,421	
10.0	31.42	157.08	2.46	72,260	
9.5	30.42	147.08	2.40	66,009	
9.0	29.41	137.11	2.33	59,740	
8.5	28.40	127.19	2.25	53,515	
8.0	27.38	117.35	2.17	47,619	
7.5	26.36	107.60	2.09	42,053	
7.0	25.32	97.99	2.00	36,648	
6.0	23.18	79.27	1.81	26,830	
5.0	20.94	61.42	1.61	18,491	
4.0	18.54	44.73	1.40	11,710	
3.0	15.90	29.55	1.12	6,189	
2.0	12.87	16.35	0.81	2,476	
1.0	9.02	5.87	0.38	417	

TABLE IV.

Table showing gaugings taken at each hour during the day and night in the circular brick sewer at Jackson Street, Memphis, Tenn., with the corresponding velocity and discharge of water as determined from Kutter's formula by the use of Hering's diagrams.

Diameter of sewer, 20 inches (circular).

Rate of fall, 1 in 460.

Assumed coefficient of friction, .015.

December 19th and 20th, 1880.				June 17th and 18th, 1881.			
HOUR.	Measured Depth of Water.	Computed Velocity of Flow.	Computed Discharge during the Hour.	HOUR.	Measured Depth of Water.	Computed Velocity of Flow.	Computed Discharge during the Hour.
	INCHES.	FEET PER SECOND	GALLONS PER HOUR.		INCHES.	FEET PER SECOND.	GALLONS PER HOUR.
6 P.M.	14.5	2.78	126,819	6 P.M.	11.5	2.59	90,555
7 "	14.5	2.78	126,819	7 "	11.5	2.59	90,555
8 "	14.0	2.76	121,231	8 "	12.5	2.67	103,133
9 "	14.0	2.76	121,231	9 "	11.5	2.59	90.555
10 "	13.0	2.70	109,139	10 "	11.0	2.55	84,421
11 "	13.0	2.70	109,139	11 "	10.0	2.46	72,260
12 Midnight.	13.0	2.70	109,139	12 Midnight.	10.0	2.46	72,260
1 A.M.	12.5	2.67	103,133	1 A.M.	9.0	2.33	59,740
2 "	11.5	2.59	90,555	2 "	8.0	2.17	47,619
3 "	10.5	2.51	78,421	3 "	9.5	2.40	66,009
4 "	7.5	2.09	42,053	4 "	9.5	2.40	66,009
5 "	8.5	2.25	53,515	5 "	9.5	2.40	66,009
6 "	13.0	2.70	109,139	6 "	10.0	2.46	72,260
7 "	13.0	2.70	109,139	7 "	11.5	*b* 2.59	90,555
8 "	13.5	2.73	115,186	8 "	12.0	2.63	96,793
9 "	13.5	2.73	115,186	9 "	12.5	2.67	103,133
10 "	13.0	2.70	*114,902	10 "	12.5	2.67	103,133
11 "	*13.0	2.70	*117,925	11 "	12.5	2.67	103,133
12 Noon.	*13.5	2.73	*116,763	12 Noon.	12.5	2.67	103,133
1 P.M.	13.0	2.70	109,139	1 P.M.	12.5	2.67	103,133
2 "	14.0	2.76	121,231	2 "	12.0	2.63	96,793
3 "	13.5	2.73	115,186	3 "	12.0	2.63	96,793
4 "	12.5	*a* 2.67	103,133	4 "	12.0	2.63	96,793
5 "	13.0	2.70	109,139	5 "	12.0	2.63	96,793

Total Discharge........................2,547,262
Average per Hour........................106,136
Excess of Maximum Flow above the Average..........19.4 per cent.

*NOTE.—Depth of Water at
10.30 A.M.............................15 inches.
11.30 A.M.............................14 inches.
a Velocity of Floats.......................2.53

Total Discharge........................2,072,570
Average per Hour........................86,357
Excess of Maximum Flow above the Average......... 19.4 per cent.

b Velocity of Floats..............2.60 to 2.82